3. Third and fourth years: The fuel tax should be increased $0.0026/L, if necessary to close the gap between identified needs and revenues, in addition to any change indicated by the CPI.

The forecast revenue under the recommended plan and the needs in five-year increments are compared below.

Period	Needs ($ millions)	Federal Aid Plus Revenue ($ millions)	Needs Met (percentage of total)
1978-1982	2945.3	1892.4	64.3
1983-1987	2827.5	3010.1	106.5
1988-1992	3966.5	3580.2	90.3
1993-1997	4734.7	4759.5	100.5

The rationale for the recommended package includes all of the factors discussed above. The user concept is maintained in the package by using the existing road-user tax structure. This also means that the collection machinery already exists; no significant new administrative organization is required, which will minimize administrative costs. The package provides for the effect of inflation by tying the user taxes to automatic changes in the state CPI (which will be prepared regularly). This is an important feature because the current user-tax structure is not responsive to inflation. The first-year increase will bring the tax rate to where it would have been if highway-user taxes had been tied to the inflation rate since the last fuel-tax increase in 1975. Population growth and travel are accounted for by increases not only in the fuel tax but also in vehicle registration and truck fees.

The taxes are spread over a broader base. This feature of the package reduces the reliance on the fuel tax as the primary source of revenue. Because of the technological changes that are occurring, proportionally less income will be realized from the fuel tax.

(Because the federal government is currently carrying out a weight allocation study to determine the effects of heavy trucks on highway costs, weight fees were not discussed in this report; the entire problem of weight allocation costs should be reviewed when the federal study has been completed.)

The opportunity for periodic review is a feature of the recommended package. Because the transition period for implementation covers several years, it will be possible to review needed increases in light of updated needs studies.

Because of the transition-period feature, the first-year increase to users will be approximately $16/passenger-type vehicle or about 10 percent. The transition period will allow for timely planning by the various highway agencies that use the funds and permit a gradual increase in state highway spending with respect to personal income.

It should be noted that these recommendations are specific for the state of Arizona. Although many states currently face funding problems, it is not possible to set forth recommendations that would be applicable to the travel and taxing situations in all states. This study did provide a set of recommendations that would address the problems in Arizona.

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Methodology for Evaluating Impacts of Energy, National Economy, and Public Policies on Highway Financing and Performance

Fred L. Mannering and Kumares C. Sinha

The need to conserve energy, inflationary pressures, decreasing user tax revenues, and recent national automotive policy decisions have created problems that have seriously affected the state highway financing process. This paper discusses the development and application of a computer model that can be used to analyze and estimate the complex interactions among the factors influencing highway financing and their ultimate impacts on highway performance. The model uses the national energy and economic forecasts developed by Data Resources, Inc., along with a set of possible highway policy options, and simulates their effects on factors such as vehicle fuel efficiency, commercial and noncommercial vehicle travel, fuel consumption, revenue generation, and highway maintenance and capital expenditures. Application of the model to the Indiana problem indicated that an overall deterioration in highway performance can be expected because the revenue required to stabilize or improve highway performance is enormous. However, the scenarios tested showed that highway policy options such as revised highway performance criteria and programs to reduce future highway use can have a significant impact on future highway performance. Thus, combinations of increased tax rates and non-revenue-generating highway policy options may be necessary to ensure the sustenance of a tolerable level of highway performance in the future.

The current state highway financing process is confronted by a number of serious problems that are being aggravated by recent economic conditions and national policy decisions. On the one hand, highway construction, operation, and maintenance costs have increased drastically in recent years while, on the other hand, road-user tax revenues have remained the same or decreased. These problems have led to the deferral of many needed highway improvement projects and, consequently, overall highway performance has suffered. Moreover, the long-term impacts that national and regional energy-conservation policies will have on the state highway financing process are not clearly understood.

It is clear that there is a definite need to examine possible legislative actions to substantially change the state revenue-generating structure and tax rates (or both) in order to provide sufficient resources for highway construction, operation, and maintenance. The intent of the study reported in this paper was to provide a tool, in the form of a computer model, that could be used to systematically evaluate the impacts that various proposed highway-related legislative decisions may have on highway performance in Indiana. [This paper is a brief summary of the study; details of model development and application are given elsewhere (1).]

The 1976 National Highway Inventory and Performance Study (NHIPS) (2) was the first major study to apply the exacting methods of measuring highway performance that were introduced in the 1974 National Highway Needs Report (3). This made possible detailed projections of highway service, physical conditions, and operating conditions under various highway-revenue scenarios. However, the 1976 NHIPS, and most other studies in this area, did not explicitly consider many of the interactive economic factors that affect future highway-financing and performance forecasts.

An overview of the modeling procedure used in the study reported here is shown in Figure 1. National macroeconomic forecasts are used as input to make projections of fuel efficiency, fuel consumption, state highway-user revenues, highway performance, and highway improvements. Fuel-efficiency projections, made on the national level, are a critical component in the determination of fuel-consumption projections, which are, in turn, used in the estimation of future state highway-user revenues. In addition, Indiana population projections were made by the cohort survival method and used to estimate the number of registered vehicles and the number of licensed drivers, both of which are also used in the calculation of state highway-user revenues. Revenues from sources such as federal aid are estimated exogenously and combined with the internally projected state highway-user revenues to determine the total funds available for highway expenditures. Finally, current highway conditions are simulated internally and used with projections of highway improvements and other factors to estimate future highway performance—which is the final step of the modeling procedure.

MODELING PROCEDURE

National Macroeconomic Forecasts

The three national macroeconomic forecasting models developed by Data Resources, Inc. (DRI), TRENDLONG 0978, CYCLELONG 0978, and PESSIMLONG 0978, were used to provide a probable range of future economic conditions to the target year 1990 (4). TRENDLONG essentially represents a long-run stable U.S. economy. CYCLELONG simulates a cyclical economic behavior and forecasts the business cycles that have historically characterized the U.S. economy. The projected 1990 gross national product (GNP) resulting from CYCLELONG is 2.2 percent less than that projected by the TRENDLONG model. PESSIMLONG projects essentially the same price, exogenous factors, and final demand behavior that has typified the U.S. economy in the past 10 years. The resultant 1990 GNP is less than that projected by either of the other two models.

The basic assumptions underlying these macroeconomic forecasts are given in Table 1 (4). The results of these models provided national projections of new car sales, automobile ownership, gasoline price deflators, industrial production, iron and steel production, and deflators for highway improvements, all of which were used at various stages of the present study.

Fuel-Efficiency Projections

Fuel efficiencies were projected on a national level and applied to Indiana. Five vehicle types were considered: (a) automobile, (b) motorcycle, (c) bus, (d) single-unit truck, and (e) combination truck.

The projection of automobile-fleet fuel efficiencies was made by using a cohort survival technique to project the automobile population by model year. The modeling approach considered the possible effects of the national economic climate and included a high degree of interaction between prevailing economic conditions and the model parameters. The basic elements of the model are to (a) project the number of automobiles in use by model year, (b) project automobile fuel efficiencies by model year, and (c) establish relative automobile use by model year. The average automobile-fleet fuel efficiency in any given year is then determined by appropriately weighting the fuel efficiencies of each model year. The computation procedure used is outlined in Figure 2. National projections of new car sales and automobile ownership (which are used internally to project scrappage rates) are provided as input from the DRI economic forecasts.

Due to data limitations, the fuel-efficiency values for other types of vehicles could not be estimated in such a detailed manner. Therefore, these estimates were made simply by extrapolating recent national values (5).

Fuel-Consumption Projections

Fuel consumption has a direct impact on fuel tax revenue, which historically has been the largest single source of highway revenue. The approach most commonly used to project fuel consumption is to estimate (a) future vehicle travel (VT) and (b) future fleet fuel efficiencies. Once these two elements have been determined, total fuel consumption can be determined by dividing VT by fleet fuel efficiency. An outline of this approach is shown in Figure 3.

Due to problems of multicollinearity, it was not possible to develop a regression equation by which to forecast total VT. Consequently, the VT equation given by Poister, Larson, and Rao (6, Figure 1), in which estimates of VT are made by assuming a growth rate and a demand elasticity of VT with respect to fuel price, was used. The growth-rate and demand-elasticity assumptions were made from an analysis of existing data and relevant literature (5, 7). Future fuel prices were determined by using the gasoline-price-deflator forecasts provided by the three DRI macroeconomic models.

The separate estimation of commercial VT growth (composed primarily of combination truck VT) is essential because of the large contribution these ve-

Figure 1. Overview of simulation procedure.

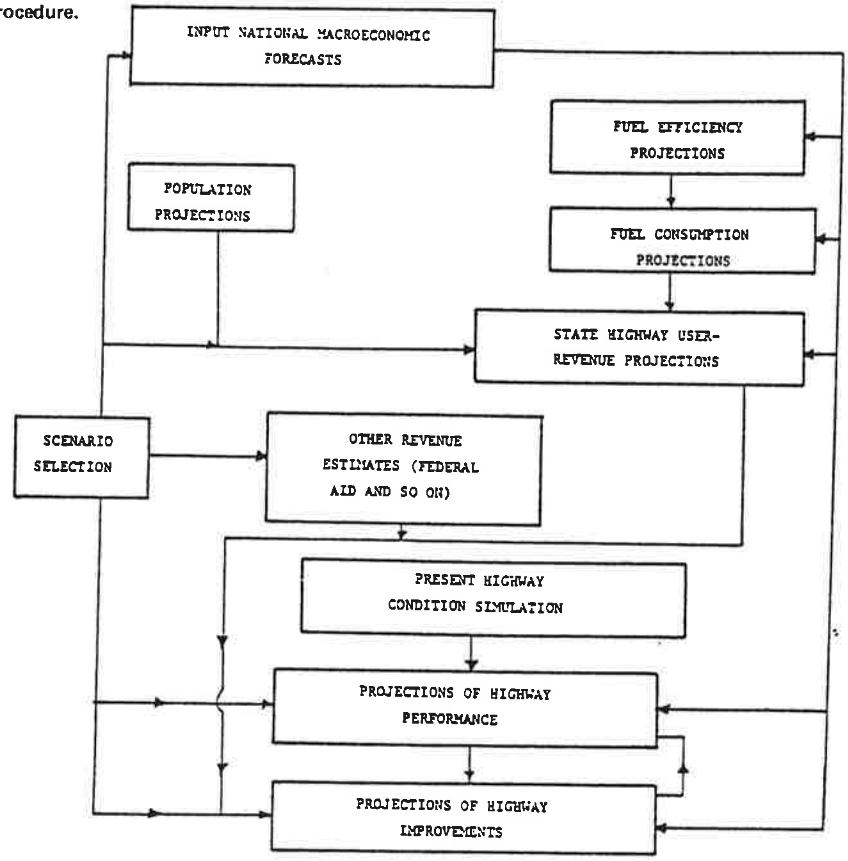


Table 1. Major assumptions underlying DRI macroeconomic forecasts.

Factor Forecast	TRENDLONG	CYCLELONG	PESSIMLONG
Fiscal policy	Federal expenditures increase at compound annual rate of 8.8 percent; federal budget is in balance after 1986	Federal expenditures increase at compound annual rate of 9.3 percent	Federal expenditures increase at compound annual rate of 10.6 percent
Monetary policy	Money supply is tightened in 1980 as inflation accelerates; stable credit is promoted	Fluctuations in policy contribute to severity of cyclic economic behavior	Same as under CYCLELONG
Consumer behavior	Low inflation rate and job security increase consumer confidence	Cyclic variations in sentiment result in large fluctuations in expenditures for durable goods	Same as under CYCLELONG
Business behavior	Decisions are made in a stable environment	Output fluctuations and uncertainty result in uncertainty and investor caution	Same as under CYCLELONG
Inflation rate	Capacity utilization and energy problems affect immediate future; steady improvement beginning in the early 1980s	Continual boom-bust pattern increases average rate	Aggressive wage and price behavior increases rates and also severity of economic slowdowns

hicles make to pavement deterioration. The estimation technique used calculates future changes in commercial VT by assuming that the change in total commercial VT is proportional to the change in motor truck intercity shipping. A regression equation was developed to project intercity shipping by using the national business index and Indiana steel production as independent variables. Provisions were also made for possible changes in truck capacities and truck capacity use, both of which will affect the proportionality assumption.

The total VT was segregated by vehicle type in the base year by using the national apportionments (5). The growth rate in combination truck VT was assumed to equal the growth rate in commercial VT, and projections of other vehicle VT values were made by extrapolating recent apportionment trends (5). Thus, fuel consumption can be determined simply by dividing the VT values by the appropriate vehicle fuel efficiencies.

State Highway-User Revenue Projections

Projections of state user revenue sources were made by categorizing such sources into four basic areas:

1. Revenues derived from motor vehicle registrations,
2. Revenues derived from license fees,
3. Revenues derived from state taxes on motor fuel, and
4. Revenues derived from miscellaneous user sources.

Automobile registration projections were made by assuming that an automobile saturation will be reached, at which time the number of vehicles per capita will stabilize. An appropriate saturation value was selected on the basis of findings in relevant literature (8, 9), and a power curve was fitted to the original data so that annual estimates of automobile ownership per capita could be calculated. Indiana population projections were made by the cohort survival method so that Indiana automobile ownership can be determined annually by simple multiplication.

Single-unit truck, bus, and motorcycle registrations were assumed to be proportional to automobile registrations. Combination truck registrations were projected by using an equation that uses the national business

Figure 2. Computation procedure for automobile fuel-efficiency model.

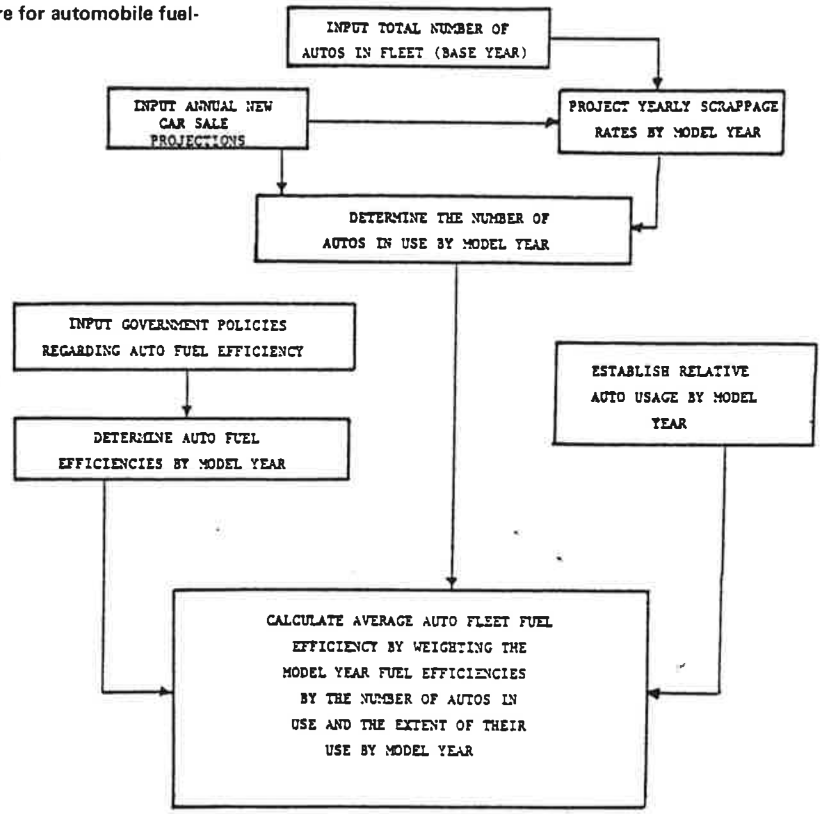
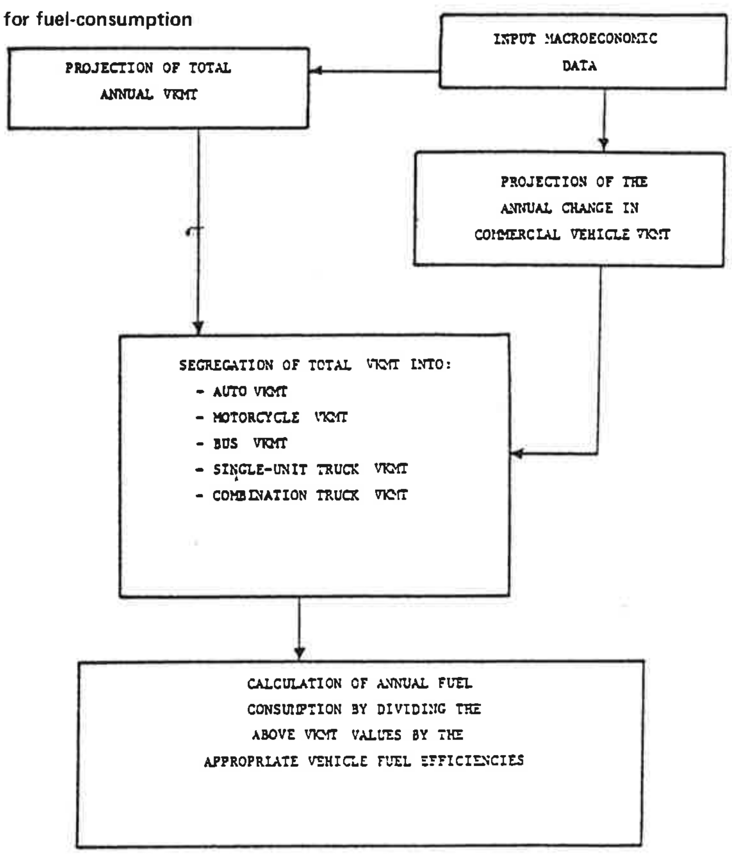


Figure 3. Simulation procedure for fuel-consumption model.



index and an assumed growth rate as independent variables. Provisions were also made for possible changes in truck weight distributions as such changes will directly affect the revenues collected from truck registrations.

Numbers of licensed drivers were estimated by extrapolating the ratios of licensed drivers per 1000 of driving age population by using historical data (5) and multiplying these projections by the driving age population (in thousands) determined from the cohort population projections.

Fuel consumption was estimated by using the techniques described above, and the revenues from this source were calculated by using the fuel tax rate. Revenues from miscellaneous user sources, such items as chauffeur licenses, distributor licenses, and a variety of motor fuel and vehicle sources, were assumed to be a constant percentage of the total projected state road-user revenue.

Highway Performance Projections

The relative performance of highway sections was considered by functional classification (e.g., Interstate, arterial, collector, and so on) and measured in terms of a condition index. The condition indices, which are scaled from 0 to 100, were derived by appropriately weighting relevant highway characteristics. The highway characteristics used were (a) pavement thickness, (b) pavement condition, (c) peak-hour volume-to-capacity ratio, and (d) lane width.

Because the base-year data needed to project highway performance were not readily available in detailed form, a simulation procedure was developed to provide the level of data aggregation necessary. The simulation used a Monte Carlo sampling technique to create a sample of roadway sections that were categoried by highway functional classification. The summary of statewide highway data presented in the 1976 NHIPS was used as a basis to assign a set of attributes to each roadway section that could then be used to project the four basic determinants of the condition index. These section attributes included (a) section length, (b) traffic volume, (c) number of lanes, (d) pavement thickness, (e) pavement condition, (f) peak-hour volume-to-capacity ratio, and (g) lane width. Each roadway section was aged by projecting traffic volume growth by vehicle type, axle-load accumulations, and so on. In addition, roadway sections were considered for seven major types of capital improvements: new location, reconstruction, isolated reconstruction, major widening, minor widening, resurfacing, and resurfacing and shoulder improvements. A priority-setting technique based on the cost-effectiveness of improvement types and the overall condition index of the section was developed and applied so that the limited funds available for capital improvements could be optimally allocated to roadway sections. After the assignment of a capital improvement type, the section attributes were appropriately redetermined and the condition index of the section was recalculated.

MODEL APPLICATION

A number of scenarios were considered to analyze the effects that legislative policy options, revised highway performance criteria, changes in future travel characteristics, and prevailing economic conditions may have on the performance of the Indiana highway system. [In discussing the results of these analyses, the scenarios are identified by an alphanumeric coding system in which the letter denotes the model used to provide the economic data (T = TRENDLONG, C = CYCLELONG, and P = PESSIMLONG) and the number refers to a specific option of possible legislative alternatives along with other attendant assumptions.]

In all scenarios tested, it was assumed that legislative policy options would have no effects on the macroeconomic data used as input. The only exception was that the gasoline price deflator would be influenced by changes in fuel tax rates. This assumption is reasonable; in a recent study, it was observed that a probable range of highway funding options have negligible impacts on economic conditions (2).

Revenue Assumptions

Revenues from federal agencies, state general-fund appropriations, and other nonstate road-user tax sources were estimated by assuming that such revenues would be proportional to the revenues collected from state road-user taxes. This assumption was based on historical data and current federal fund-allocation procedures.

Disbursement Assumptions

Highway disbursements were categorized into four broad classifications:

1. Local capital outlays, which includes all expenditures for capital improvements on the local road functional classification;
2. Nonlocal capital outlays, which includes all expenditures for capital improvements on nonlocal functional classifications (e.g., Interstates, arterials, and collectors);
3. Structure costs, which includes funds allocated for the rehabilitation of roadway structures; and
4. Routine maintenance, administration, and all others.

It was assumed that disbursement category 4 would increase at an annual rate that is proportional to the annual increase in the price deflator for highway capital improvements. Once this disbursement was calculated, an assumed fixed percentage of the remaining funds was allocated to structures, local, and nonlocal capital outlays. These percentages were estimated by using historical data and the values estimated by previous studies (2, 10).

Distribution of Nonlocal Capital Funds Among Functional Classifications

Two alternative funding distributions were developed by using, as a basis, the funding distributions given in the 1976 NHIPS (2) and the estimation of future Indiana capital improvement needs made for the 1972 National Highway Needs Study (10). The first funding distribution (series 1) was used for all scenarios that assume that the highway performance criteria and the travel characteristics will remain unchanged over the time period of the present study. The series 1 distribution allocates a relatively large percentage of capital improvement funds to high-volume facilities. This distribution reflects the state preference for maintaining the condition of high-volume facilities as opposed to low-volume facilities (which are given a lower priority, particularly when funding levels are not sufficient to meet highway needs).

The second funding distribution (series 2) was used for the scenarios that assumed changes in highway performance criteria or in travel characteristics. These assumed changes will result in a considerable reduction in the need for capital improvements on high-volume facilities. Consequently, the series 2 distribution allocates a greater amount of funding to low-volume facilities than does the series 1 distribution.

Discussion of Options

Table 2 summarizes the assumptions made for the five options presented in this paper.

Option 1

This option was designed to analyze the effects that continuing the current Indiana highway taxing policies will have on future Indiana highway performance. It was examined in terms of all three macroeconomic forecasting models so that the full impacts of varying national economic conditions could be assessed. The 1990 values of selected model parameters are summarized below (1 km = 0.62 mile and 1L = 0.26 gal).

Parameter	Scenario T-1	C-1	P-1
Total VT (km 000 000s)	85 438	82 550	79 872
Combination VT (km 000 000s)	4 984	4 597	4 667
Total fleet efficiency (km/L)	7.82	7.78	7.76
Retail gasoline price ($/L)	0.35	0.39	0.44
Total revenues ($000s)	586 272	570 112	560 827
Nonlocal capital outlays ($000s)	182 056	167 843	153 113
Price deflator for capital outlays (1975 = 1.00)	2.75	2.92	3.38
Other noncapital disbursements ($000s)	314 546	319 599	332 299

As might be expected, when the results for the three models are compared, the high inflation rates and lower industrial productions of the CYCLELONG and PESSIMLONG models result in lower VT values, lower fleet fuel efficiencies, higher gasoline prices, and lower highway revenues (which will have less buying power per dollar).

The effects that economic conditions have on highway performance are shown in the table below, which summarizes the percentage changes in the condition indices of each functional classification between 1976 and 1990.

Functional Classification	Scenario T-1	C-1	P-1
Rural			
Interstates	-11.2	-9.8	-8.9
Other principal arterials	-5.8	-4.1	-3.6
Minor arterials	-9.6	-7.6	-7.4
Major collectors	-22.5	-19.3	-18.7
Minor collectors	-29.6	-25.6	-25.4
Urban			
Interstates	-13.5	-12.5	-12.1
Other freeways and expressways	-14.4	-13.2	-10.9
Other principal arterials	-10.4	-10.3	-9.6
Minor arterials	-19.3	-19.1	-17.6
Collectors	-18.5	-18.5	-16.4

It is apparent that, if current highway taxing policies are continued, a considerable deterioration in Indiana highway performance, particularly on lower-volume facilities, can be expected. This loss in highway performance will arise from an overall degradation in system pavement conditions and increased congestion.

As for the impacts of economic conditions, in this option, the more pessimistic economic assumptions result in less deterioration of highway performance. This is due to the fact that pessimistic economic assumptions result in (a) less congestion because VT growth rates are lower and (b) less pavement degradation due to loading because the growth in intercity shipping is more moderate. For this option, these two factors offset the effects of decreasing highway revenues and reductions in per dollar buying power. The result is that the reduction in highway performance is lower.

It must be pointed out, however, that it should not be concluded that more-pessimistic economic assumptions will necessarily result in less deterioration in highway performance. In some cases, revised highway performance standards and travel characteristics will result, on certain functional classifications, in less reduction in highway performance, even under more-optimistic economic scenarios. This is due to the fact that highway performance is the result of the interaction of economic conditions, the performance criteria used, the travel characteristics assumed, and the physical attributes of each functional classification.

Option 2

Option 2 uses essentially the same assumptions as option 1, except for the implementation in 1980 of a 2.9 cents/L (11 cents/gal) gasoline tax [i.e., an increase over current gasoline tax rates of 0.8 cents/L (3 cents/gal)]. The increase in gasoline tax, which is also accompanied by increases in funds from other nonstate road-user revenue sources, results in a 27 percent increase in total highway revenues in calendar year 1980 (see Table 3) when the TRENDLONG data are used. The impact that the additional revenue has on Indiana highway performance is summarized below.

Functional Classification	Scenario T-1	T-2	T-3
Rural			
Interstates	-11.2	-10.0	-4.2
Other principal arterials	-5.8	-3.1	+1.8
Minor arterials	-9.6	-5.8	-1.1
Major collectors	-22.5	-18.6	-8.4
Minor collectors	-29.6	-27.0	-17.7
Urban			
Interstates	-13.5	-10.7	-4.4
Other freeways and expressways	-14.4	-12.5	-9.5
Other principal arterials	-10.4	-9.7	-6.7
Minor arterials	-19.3	-18.8	-15.6
Collectors	-18.5	-15.6	-10.3

When the results of scenarios T-1 and T-2 are compared, it is evident that the increased revenue results in only moderate improvement in highway performance after a certain threshold level. This is due to the fact that the relationship between capital investment and performance is asymptotic [see Figure 4 (2)] and, therefore, a large increase in capital investment may result in only modest increases in the condition index.

Option 3

Option 3 assumes that a 20 percent ad valorem gasoline tax is implemented in 1980 in an attempt to keep pace with the inflationary pressures that, under the TRENDLONG assumptions, increase capital improvement costs by 275 percent between 1975 and 1990. Table 3 summarizes total highway revenues generated by the three options discussed thus far. The ad valorem tax obviously generates the most revenue. This is particularly evident for the mid-1980s, when decreasing fuel consumption actually reduces the total revenues collected under options 1 and 2.

Table 2. Summary of option assumptions.

Effect Analyzed	Option 1	Option 2	Option 3	Option 4	Option 5
Road-user tax rates	Same as 1979	Gasoline tax of 2.9 cents/L	20% ad valorem tax on gasoline	Gasoline tax of of 2.9 cents/L	Gasoline tax of 2.9 cents/L
Fraction of total revenues obtained from nonstate road-user tax sources	0.45	0.45	0.45	0.45	0.45
Distribution of capital funds to functional classifications	Series 1	Series 1	Series 1	Series 2	Series 2
Other	None	None	None	Revised improvement standards	Peaking reduced by 20 percent

Note: 1 L = 0.26 gal.

Table 3. Total Indiana highway revenues (thousands of constant 1978 dollars).

Year	Scenario T-1	Scenario T-2	Scenario T-3	Year	Scenario T-1	Scenario T-2	Scenario T-3
1976	549 267	549 267	549 267	1984	307 606	389 102	543 041
1977	516 278	516 278	516 278	1985	285 865	360 922	530 444
1978	486 056	486 056	486 056	1986	268 662	338 661	522 659
1979	450 232	450 232	450 232	1987	252 034	317 159	513 659
1980	418 227	532 702	618 414	1988	238 038	299 188	509 027
1981	385 005	489 594	594 247	1989	225 137	286 683	505 465
1982	355 249	450 992	573 138	1990	213 189	267 465	502 097
1983	330 153	418 414	554 076				

Although highway performance under scenario T-3 is noticeably better than that under scenario T-1 (see above), it is evident that, despite a considerable increase in revenues, it will still deteriorate on most functional classifications. This indicates that the generated revenue is still not sufficient to perform the capital improvements necessary to maintain 1975 conditions. There are essentially two reasons for this. First, the asymptotic relationship between investment and performance means less improvement than would be expected if a linear relationship existed. Second, the ad valorem tax is indexed to the price of fuel, which, in the TRENDLONG forecast, increases at a rate that is less than the rate of increase in the cost for capital improvements and, therefore, inflation continues to erode highway dollars (although to a lesser extent than under options 1 and 2).

Option 4

This option was designed to evaluate the effects that revised highway performance standards will have on future Indiana highway performance. This revision was achieved by attaching more importance to pavement conditions and less importance to volume-to-capacity ratios and lane widths. Such a revision in standards would permit the state to concentrate more of its capital funds on pavement rehabilitation and spend less on costly widening improvements.

This option also included the assumption of the 1980 implementation of 2.9 cents/L gasoline tax. It was further assumed that nonlocal capital funds would be distributed among functional classifications by the series 2 distribution, which allocates a greater share of capital funds to lower-volume facilities. The resulting impacts on Indiana highway performance are summarized below.

Functional Classification	Scenario T-2	Scenario T-4	Scenario P-4
Rural			
Interstates	-10.0	-4.5	-2.5
Other principal arterials	-3.1	-5.7	-4.9
Minor arterials	-5.8	-6.5	-5.4
Major collectors	-18.6	-9.4	-8.1
Minor collectors	-27.0	-19.8	-21.2
Urban			
Interstates	-10.7	-11.3	-10.1
Other freeways and expressways	-12.5	-13.0	-9.8
Other principal arterials	-9.7	-9.9	-7.7
Minor arterials	-18.8	-16.6	-14.9
Collectors	-15.6	-6.5	-4.4

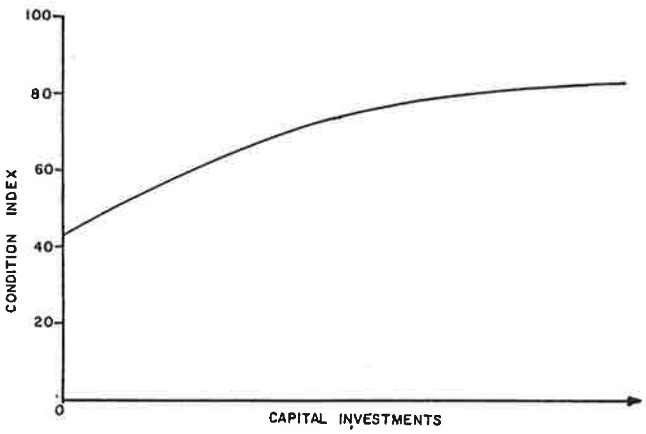
When scenarios T-2 and T-4 are compared, it is apparent that the latter generally results in less highway performance deterioration. This revision of standards means that the performance deterioration of the high-volume facilities under scenario T-4 will be comparable to that under scenario T-2 despite the fact that the funds allocated to these facilities under the series 2 distribution are less. Overall, the pavement conditions are improved considerably under this option, as expected. However, the volume-to-capacity ratios are generally higher, indicating a greater service loss.

This option was also run by using the PESSIMLONG model to evaluate economic impacts under the revised performance standards. The economic impact results for high-volume facilities were much the same as those observed for option 1. This indicates that the reduced volume-to-capacity ratios and commercial VT values associated with the PESSIMLONG model offset the effects of decreases in capital investments. However, for the lower-volume facilities, which generally require more frequent resurfacing, the additional funds allocated to resurfacing improvements by the TRENDLONG model result in significantly improved pavement conditions. This, and the increased emphasis on pavement conditions in the revised performance criteria, offsets the lower volume-to-capacity ratios and commercial VT values observed for the PESSIMLONG model to a greater degree than was the case with the higher-volume facilities. Consequently, the difference in the performance impacts of the two economic models is less conclusive on lower-volume facilities. For the case of rural minor collectors, for example, scenario T-4 resulted in better overall pavement conditions than did scenario P-4 and, although the volume-to-capacity ratios were higher, the overall adverse effect on highway performance was less.

Option 5

This option was designed to evaluate the impacts that a reduction in the current peaking characteristics would have on Indiana highway performance. Such reductions can result from carpooling and vanpooling, staggered working hours, and so on. It was assumed that the 2.9

Figure 4. Generalized relationship between highway investment and highway performance (one curve for each functional classification).



cents/L gasoline tax would be implemented in 1980 and that the series 2 capital-outlay distribution would be used. In addition, it was assumed that there would be a 20 percent reduction in the percentage of the average daily travel occurring during peak periods by 1990.

This option resulted in an improved highway performance; the performance levels were considerably higher than those obtained under scenario T-2, which assumes a continuation of current peaking characteristics. This improvement results from the obvious reductions in volume-to-capacity ratios and the improvement in pavement conditions because more funds can be allocated to pavement rehabilitation as the need for widening diminishes:

Functional Classification	Scenario T-2	T-5	P-5
Rural			
Interstates	-10.0	-2.8	-1.1
Other principal arterials	-3.1	-2.6	-1.0
Minor arterials	-5.8	-1.8	-0.6
Major collectors	-18.6	-6.5	-8.1
Minor collectors	-27.0	-14.9	-10.9
Urban			
Interstates	-10.7	-8.0	-6.2
Other freeways and expressways	-12.5	-6.0	-4.4
Other principal arterials	-9.7	-6.3	-3.8
Minor arterials	-18.8	-12.4	-9.3
Collectors	-15.6	-8.1	-2.7

The increased emphasis on pavement rehabilitation resulted in better pavement conditions under scenario T-5 than under scenario P-5, despite the lower loading conditions in the latter. However, the higher volume-to-capacity ratios under scenario T-5, and their relative importance in estimating highway performance, offset the improved pavement conditions and, consequently, highway performance deterioration was generally less under scenario P-5.

CONCLUSIONS

The options considered in this paper indicate that a general deterioration in Indiana highway performance can be expected in the future due to the enormous amount of revenue needed to sustain real highway investment levels. Alternatives other than generation of additional revenue, such as revision of performance standards and reductions in peaking characteristics, can minimize future highway performance deterioration but, realistically, a combination of increased taxes and additional non-revenue-generating alternatives will likely provide the most acceptable solution to the highway financing problem. The specific combination will depend on public willingness to accept additional taxation and public tolerance of additional highway performance deterioration.

REFERENCES

1. F. L. Mannering. Methodology for Evaluating the Impacts of Energy, National Economy, and Public Policies on Highway Financing and Performance. Purdue Univ., West Lafayette, IN, Rept. JHRP-79-6, July 1979.
2. 1976 National Highway Inventory and Performance Study. Federal Highway Administration, Rept. FHWA-PL-78-006, Sept. 1977.
3. 1974 National Highway Needs Report. Federal Highway Administration, 94th Congress, 1st Session, House Document 94-95, U.S. Government Printing Office, 1975.
4. U.S. Long-Term Review: The Economic Outlook—1978 to 1990. Data Resources Inc., Lexington, MA, Fall 1978.
5. Highway Statistics. Federal Highway Administration, 1960-1976.
6. J. Poister, T. Larson, and S. Rao. Fiscal Planning and Highway Programming: The Pennsylvania Response to a Changing Environment. TRB, Transportation Research Record 654, 1977, pp. 16-22.
7. N. Erlbaum, D. Hartgen, and G. Cohen. Automotive Energy Forecasts: Impact of Price, Availability, and Efficiency. Planning Research Unit, New York State Department of Transportation, Albany, Dec. 1977.
8. W. Bottiny. Trends in Automobile Ownership and Indicators of Saturation. HRB, Highway Research Record 106, 1965, pp. 1-21.
9. J. R. McCarthy. State Highway Finance and User Taxation in Indiana. Purdue Univ., West Lafayette, IN, Rept. JHRP-76-26, Oct. 1976.
10. 1972 National Highway Needs Report. Federal Highway Administration, 92nd Congress, 2nd Session, House Document 92-266, U.S. Government Printing Office, 1972.

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